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USATRECOM TECHNICAL REPORT 65-22

EFFECT OF EROSION RESISTANT BOOTS ON UH-1B/D TAIL ROTOR BLADES

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By

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May 1965

U. S. ARMY TRANSPORTATION RESEARCH COMMAND

FORT EUSTIS, VIRGINIA

CONTRACT DA 44-177-AMC-252(T)

BELL HELICOPTER COMPANY

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This report was prepared by Bell Helicopter Company in accordance with the requirements of Contract DA 44-177-AMC-252(T) initiated by the U. S. Army Transportation Research Command, Fort Eustis, Virginia.

This test program determined that polyurethane protective boots installed on the tail rotor blades produce no operational or fatigue life problems on the UH-1B/D tail rotor dynamic components.

The protective boots for UH-1B/D tail rotor blades are recommended for use on blades that are being prematurely retired due to erosion by sand and dust and for installation on blades when operation of the helicopter in an abrasive environment can be expected.

Task 1P121401A14176
Contract DA 44-177-AMC-252(T)
USATRECOM Technical Report 65-22
May 1965

EFFECT OF EROSION RESISTANT BOOTS ON UH-1B/D TAIL ROTOR BLADES
(Bell Helicopter Report 299-099-276)

by

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Prepared By

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for

U. S. ARMY TRANSPORTATION RESEARCH COMMAND
Fort Eustis, Virginia

ABSTRACT

This report presents the results of a flight test program conducted to evaluate erosion boots installed on the outboard 18 inches of the UH-1 helicopter tail rotor blades. The report is not concerned with the erosion resistant qualities of the boot, but with the effect of the boot installation on the balance, operation, and fatigue life of the UH-1B/D tail rotor dynamic components. Loads as measured during flight tests of the tail rotor with the boots installed are compared to loads measured using a standard tail rotor. In both the balanced and unbalanced conditions no detrimental effects were encountered. The oscillatory loads recorded in either condition would not cause fatigue damage and no problems in operation were obtained with the boots installed.

FOREWORD

This report describes a program conducted to evaluate a polyurethane erosion protection boot installed on a UH-1 tail rotor. The project was conducted by Bell Helicopter Company, of Fort Worth, Texas, at the request of the U. S. Army under U. S. Army Transportation Research Command contract DA 44-177-AMC-252(T). The work was performed under the technical cognizance of Mr. E. R. Givens, USATRECOM, Fort Eustis, Virginia.

The program began 18 December 1964 and was completed 12 February 1965. Mr. F. B. Burpo was the project engineer for Bell Helicopter Company.

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SUMMARY

This report describes a test program conducted to determine the effect of an erosion protection system on the balance, operation, and fatigue life of the UH-1 helicopter tail rotor dynamic components. Flight test data are presented to show the comparison of standard tail rotor loads to the loads recorded for the tail rotor with the polyurethane boots installed on the outboard 18 inches of the blades. Also, loads are presented to show the effect of operating the tail rotor with the outboard 4-1/2 inches of the boot on one blade removed to simulate partial loss of one boot.

The data were reviewed to determine the usability of the system from an operational and fatigue life viewpoint. The results indicate that the balance, operation, and fatigue life of the tail rotor dynamic components are satisfactory with the erosion protection system installed.

INTRODUCTION

The RECITAL from the contract for this program is quoted below:

> "The exposure of the UH-1B/D helicopter to sand and dust environment has caused maintenance problems and a short life limit for the tail rotor blades. The Government has developed a polyurethane boot and bonding system to protect the main rotor blades from erosion. This protective system, with minor modifications, should be suitable for the tail rotor blades. The Government, therefore, desires a test program to determine the effect of the protective system installation on the balance, operation and fatigue life of the UH-1B/D tail rotor dynamic components. The final results of the program will be the Contractor's recommendation on the usability of the existing protective system from an operational and fatigue life standpoint."

As stated above, the program was conducted to determine the effect of the protective system installation on the balance, operation, and fatigue life of the tail rotor dynamic components. No evaluation or test of the erosion characteristics of the polyurethane boot was included.

The polyurethane boots and the bonding agents were supplied by the Government. Also, instructions for the installation of the erosion protection system were furnished by USATRECOM.

DESCRIPTION

A. Test Vehicle

A standard UH-1B helicopter, serial no. AF60-3546, was used during the subject program. A complete description of the helicopter may be found in Bell Helicopter Company report no. 204-947-085, "Detail Specification for UH-1B Utility Helicopter," by R. R. Hatton, dated May 1961.

B. Tail Rotor

The erosion protection system was installed on the blades, part no. 204-011-707-15, of a standard UH-1B tail rotor assembly, part no. 204-011-700-11.

The UH-1 tail rotor is 102 inches in diameter, uses a 0015 NACA airfoil section, and the chord length is 8.41 inches. Figure 1 shows a photograph of the blades with the erosion boot modification installed on the test aircraft.

C. Boot Installation

The polyurethane boots, as supplied to the Bell Helicopter Company, were 18 inches long, 4-1/4 inches wide, and .030 inch thick; covered the outboard 18 inches of the leading edge of the blade; and extended aft to approximately 25-percent chord. The boots were installed using Epon 934 epoxy adhesive, Parts A and B, as specified in the Government-furnished instructions.

The weight of each boot was approximately 40 grams; however, the weight of an installation on one blade, including adhesive, was approximately 60 grams.

After completion of the installation, the rotor was assembled and balanced, using the standard procedure of adding washers to the blade retention bolts.

The last part of the test program concerned testing the tail rotor components in an unbalanced condition. The outboard 25 percent (4.5 inches) of the boot installation on one blade was removed, as shown in Figure 2. The material removed weighed approximately 13 grams.

D. Instrumentation

The following channels of instrumentation were recorded using an oscillograph during the ground run and flight test program. Only one blade and yoke spindle were instrumented.

Figure 3 presents diagramatically the locations of the instrumentation strain gauges on the tail rotor shaft, yoke, and blade.

	CHANNEL	DIRECTION OF LOAD FOR + VALUES	UNITS
1.	Yoke Spindle Sta. 2.65 - Beam Bending	Blade bends away from tail boom	Inch-Pounds
2.	Yoke Spindle Sta. 2.65 - Chord Bending	Leading edge of blade in tension	Inch-Pounds
3.	Blade Sta. 11.0 - Beam Bending	Blade bends away from tail boom	Inch-Pounds
4.	Blade Sta. 11.0 - Chord Bending	Leading edge of blade in tension	Inch-Pounds
5.	Blade Sta. 21.5 - Beam Bending	Blade bends away from tail boom	Inch-Pounds
6.	Blade Sta. 21.5 - Chord Bending	Leading edge of blade in tension	Inch-Pounds
7.	Pitch Link - Axial Load	Tension	Pounds
8.	Shaft Sta. 5.81 - Perpendicular Bending	The side of the mast on the trailing edge side of the instrumented blade in compression	Inch-Pounds
9.	Shaft Sta. 5.81 - Parallel Bending	Mast bending toward the instrumented blade	Inch-Pounds
10.	Shaft - Torque	Leading edge of instrumented blade in tension	Inch-Pounds
11.	Flapping Position	Instrumented blade toward tail boom	Degrees
12.	Blade Angle *	Right rudder	Degrees
13.	Rudder Pedal Position	Right Rudder	Percent
14.	Azimuth Angle (Tail Rotor)	Instrumented blade up-vertical	

* Note: The blade angle was measured at the pitch change crosshead and will not monitor the effect of δ_3 (pitch change with flapping).

GROUND AND FLIGHT TEST PROGRAM

The ground run and flight test program conducted is outlined below. Table 1 presents a log of the ground runs and flights associated with this program and shows the configuration and tests conducted. (Note: N_{II} rpm is the engine output shaft speed.)

A. Ground Run

1. RPM sweep from flight idle to 6800 N_{II} rpm, neutral pedal

2. Tail rotor pitch change sweep

   (a) at 5800 N_{II} rpm

   (b) at 6600 N_{II} rpm

B. Level Flight Load Survey

1. Forward CG (at 7500 Lb. Gross Weight)

   (a) hover 6200, 6400, and 6600 N_{II} rpm

   (b) 60 knots 6600 N_{II} rpm

   (c) 80 knots 6600 N_{II} rpm

   (d) 100 knots 6200, 6400, and 6600 N_{II} rpm

   (e) 110 knots 6600 N_{II} rpm

2. Aft CG

   (a) repeat B.1 at 7500 lb. gross weight

   (b) 100 knots 6200, 6400, and 6600 N_{II} rpm at 6600 lb. gross weight

C. Maneuver Load Survey at 7500 Lb. Gross Weight - Forward CG Only at 6500 N_{II} rpm

1. Sideward flight left

2. Sideward flight right

3. Right turn 100 knots

4. Left turn 100 knots

5. Full power climb 55 knots

6. Stabilized autorotation 85 knots

7. Autorotation turn left 85 knots

8. Autorotation turn right 85 knots

D. Out-Of-Balance Test

With twenty-five percent of the boot material removed from the outboard end of the instrumented tail rotor blade.

1. Ground run at 6800 N_{II} rpm neutral pedal

2. Level flight, 100 knots, aft cg, 6600 lb. gross weight at 6200, 6400, 6600 N_{II} rpm

RESULTS

A. Data Presentation

1. All the data recorded during this program are presented in the tables at the end of the text. These blades are the output information from a computer and are self-explanatory, with the following exceptions:

a. Flapping angle. The total range of flapping is ±7-1/2 degrees, and this has been divided into 200 units, where zero units = -7-1/2 degrees, 100 units = zero degrees, and 200 units = +7-1/2 degrees.

b. Tail rotor blade angle. The instrumentation to monitor blade angle was connected to the pitch change crosshead and consequently will indicate only mean blade pitch and not pitch change with flapping (δ_3 effect).

c. During maneuvers, the data were reduced at the point at which maximum oscillatory loads occurred. Consequently, the mean values shown may not necessarily be the maximum steady load or displacement that occurred during the maneuver.

2. Figures 4 through 8 show graphical presentations of all oscillatory load data versus airspeed recorded in stabilized level flight and hover, and Figure 9 presents tail rotor blade pitch, oscillatory flapping angle, and rudder pedal position versus airspeed.

No significant differences were noted between the data obtained at either center of gravity extreme or between gross weights of 6600 pounds and 7600 pounds, and consequently the figures do not display gross weight or cg configurations.

Also included on Figures 4 through 9 are data for the standard tail rotor without erosion boots. These are presented as a crosshatched band on each of the figures and were compiled from available standard tail rotor data in the 6600-pound to 7600-pound gross weight configuration.

B. Operation

The polyurethane erosion protection system presented no operational problems.

C. Balance

There were no problems in balancing the blades after the boots were installed. The major difference in the weight of the blades used in this program was due to the instrumentation installed on one blade. If boots were installed on blades without instrumentation, it would be necessary to rebalance the rotor; however, this can be accomplished easily if a balancing fixture is available.

D. Fatigue Life

The flight loads measured for the tail rotor dynamic components with the erosion protection system installed were normal. An examination of the recorded data shows that no adverse effect on fatigue life of the dynamic components is expected.

Bell Helicopter Company reports numbers 204-099-263 and 205-099-135 detail the fatigue life substantiation data for the 44-foot and the 48-foot diameter main rotor configurations of the UH-1B and UH-1D helicopters. The tail rotor data included in these reports were used for comparison with the data obtained on this program.

The removal of 4.5 inches of the boot material from one blade resulted in the expected increase in flight loads. Although the magnitude of oscillatory loads recorded for mast bending and blade and yoke inplane (chord) bending were approximately two times normal, no loads were observed in the flight records for this particular unbalance condition that would cause fatigue damage.

The vibration caused by the removal of 25 percent of the boot material from one blade could not be felt by the pilots; therefore, such a loss of material could be determined only by ground inspection. Also, this loss of material would not prevent completion of a mission, but the boot should be repaired and the rotor rebalanced as soon as a loss of material is discovered.

TABLE 1
GROUND RUN AND FLIGHT LOG

Date 1965	Ground Run No.	Flight No.	G.W. Lb.	C of G In.	T/Rotor Boots Balanced/ Unbalanced	Tests Conducted	
13 Jan	107A	-	-	-	Balanced	RPM Sweep	4300 - 6850 N_{II}
						Pitch Change Sweep (20% to 100%)	5800 - 6600 N_{II}
14 Jan	-	432A	7620	125.3 (Fwd)	Balanced	Hover	6200 - 6600 N_{II}
						Level Flight 40-90 Kn.	6600 N_{II}
14 Jan	-	432B	7620	125.3 (Fwd)	Balanced	Level Flight 80-110 Kn.	6600 N_{II}
						Level Flight 100 Kn.	6200 & 6400 N_{II}
						Maneuvers	6500 N_{II}
14 Jan	-	432C	7620	135.6 (Aft)	Balanced	Hover	6200 - 6600 N_{II}
						Level Flight 40-110 Kn.	6600 N_{II}
						Level Flight 100 Kn.	6200 & 6400 N_{II}
15 Jan	-	433A	6620	135.9 (Aft)	Balanced	Level Flight 60-100 Kn.	6600 N_{II}
						Level Flight 100 Kn.	6200 & 6400 N_{II}
18 Jan	108A	-	-	-	Unbalanced	RPM Sweep	4000 - 6800 N_{II}
						Neutral Rudder Pedals	6400, 6600 & 6800 N_{II}
						Pitch Change Sweep (25% to 100%)	6600 N_{II}
19 Jan	109A	-	-	-	Unbalanced	Repeat G.R. 108A Conditions	
22 Jan	-	434A	6620	135.9 (Aft)	Unbalanced	Hover	6600 N_{II}
						Level Flight 60 Kn.	6600 N_{II}
22 Jan	-	434B	6620	135.9 (Aft)	Unbalanced	G.R. Pitch Change Sweep	6600 N_{II}
						Hover Maneuvers	6600 N_{II}
						Level Flight 60-100 Kn.	6600 N_{II}
						Level Flight 100 Kn.	6200 & 6400 N_{II}

N_{II} = Engine Output Shaft Speed in RPM

TABLE 2
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 G.R. 107-A
Ship AF60-3546 Date 13 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65 MEAN	T/R YOKE CHORD AT 2.65 OSC.
524	RPM Sweep 4300 to 6850 RPM	-	-	-221	663
525	T/R Pitch Change Sweep 100% to 20%	5800	-	932	489
526	T/R Pitch Change Sweep 25% to 100%	6600	-	-568	948
527	Rudder Kick	6500	-	-158	853

CTR NO.	T/R YOKE BEAM AT 2.65 MEAN	T/R YOKE BEAM AT 2.65 OSC.	T/R BLADE CHORD AT 11.0 MEAN	T/R BLADE CHORD AT 11.0 OSC.	T/R BLADE BEAM AT 11.0 MEAN	T/R BLADE BEAM AT 11.0 OSC.
524	-2340	321	913	565	-954	270
525	1881	351	1305	435	1269	315
526	-1086	413	87	783	-2502	378
527	-1973	321	826	739	-873	243

CTR NO.	T/R BLADE BEAM AT 21.5 MEAN	T/R BLADE BEAM AT 21.5 OSC.	T/R BLADE CHORD AT 21.5 MEAN	T/R BLADE CHORD AT 21.5 OSC.	T/R SHAFT TORQUE MEAN	T/R SHAFT TORQUE OSC.
524	-398	214	504	448	422	237
525	463	183	812	308	2310	145
526	-1141	266	84	532	607	184
527	-363	196	448	504	871	448

CTR NO.	T/R PITCH LINK RED MEAN	T/R PITCH LINK RED OSC.	T/R SHAFT PERP. BEND MEAN	T/R SHAFT PERP. BEND OSC.	T/R SHAFT PARA. BEND MEAN	T/R SHAFT PARA. BEND OSC.
524	20	20	-147	588	146	492
525	109	36	901	975	119	784
526	62	41	18	570	39	651
527	36	46	-92	349	146	412

TABLE 2

(Contd)

CTR NO.	T/R BLADE ANGLE MEAN	T/R BLADE ANGLE OSC.	T/R FLAPPING ANGLE MEAN	T/R FLAPPING ANGLE OSC.	DIR. CONT. PED. POSITION MEAN	DIR. CONT. PED. POSITION OSC.
524	5.3	-	104.6	19.6	57.5	-
525	13.2	-	102.5	21.7	21.2	-
526	-4.2	-	103.6	25.9	93.9	-
527	4.2	1.6	102.5	16.5	63.0	9.6

TABLE 3
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 Flt. 432-A
Ship AF60-3546 Date 14 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65 MEAN	OSC.
534	Hover I.G.E.	6200	0	552	647
535	Hover I.G.E.	6400	0	678	678
536	Hover I.G.E.	6600	0	631	599
537	Stabilized Level Flight	6600	40.5	-615	1183
538	Stabilized Level Flight	6600	60.5	-473	1041
539	Stabilized Level Flight	6600	78.0	-394	994
540	Stabilized Level Flight	6600	89.0	-584	1183

CTR NO.	T/R YOKE BEAM AT 2.65		T/R BLADE CHORD AT 11.0		T/R BLADE BEAM AT 11.0	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
534	979	551	921	657	571	390
535	306	551	1052	614	326	381
536	199	474	1096	570	245	353
537	-2342	413	131	921	-1007	226
538	-2403	658	219	833	-1089	381
539	-2189	872	307	921	-971	517
540	-1806	1316	350	964	-853	834

CTR NO.	T/R BLADE BEAM AT 21.5		T/R BLADE CHORD AT 21.5		T/R SHAFT TORQUE	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
534	198	276	756	420	1950	210
535	155	216	784	448	2016	224
536	-38	211	756	420	1884	197
537	-522	159	168	616	593	276
538	-617	237	252	644	579	263
539	-540	332	308	588	672	276
540	-453	367	196	700	593	329

TABLE 3

(Contd)

CTR NO.	T/R PITCH LINK RED		T/R SHAFT PERP. BEND		T/R SHAFT PARA. BEND	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
534	86	75	-18	863	195	839
535	92	48	-73	588	125	1076
536	70	48	-147	698	349	853
537	-37	48	-55	533	349	629
538	-32	43	-55	496	363	643
539	-43	86	18	606	377	825
540	-59	92	-147	661	335	867

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
534	9.9	-	89.6	23.2	26.0	-
535	9.4	-	88.6	14.7	30.0	-
536	8.5	-	100.7	13.1	33.0	-
537	1.7	-	96.5	18.4	58.0	-
538	1.1	-	94.9	21.1	60.0	-
539	1.8	-	96.5	29.0	58.0	-
540	2.1	-	94.9	36.9	57.0	-

TABLE 4
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 Flt. 432-B
Ship AF60-3546 Date 14 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65 MEAN	T/R YOKE CHORD AT 2.65 OSC.
544	Sideward to Right	6500	25.0	3000	1184
545	Sideward to Left	6500	25.0	-713	940
546	Stabilized Level Flight	6600	78.0	-486	843
547	Stabilized Level Flight	6600	101.5	-340	924
548	Stabilized Level Flight	6600	113.0	-113	859
549	Stabilized Level Flight	6400	101.5	-324	1167
550	Stabilized Level Flight	6200	101.5	-32	1038
551	Turn to Left	6500	101.5	-145	1021
552	Turn to Right	6500	101.5	-324	1102
553	Full Power Climb	6500	63.0	129	713
554	Stabilized Autorotation	$319N_R$	80.0	-519	875
555	Autorotation Right Turn	$319N_R$	80.0	-519	1232
556	Autorotation Left Turn	$319N_R$	80.0	-340	1216

CTR NO.	T/R YOKE BEAM AT 2.65 MEAN	T/R YOKE BEAM AT 2.65 OSC.	T/R BLADE CHORD AT 11.0 MEAN	T/R BLADE CHORD AT 11.0 OSC.	T/R BLADE BEAM AT 11.0 MEAN	T/R BLADE BEAM AT 11.0 OSC.
544	2541	1286	2087	1043	1950	997
545	-2189	321	0	695	-1024	233
546	-1760	780	173	608	-701	485
547	-1102	1194	304	652	-485	701
548	-688	1301	391	652	-188	854
549	-979	1224	260	869	-269	827
550	-520	1469	521	869	-287	899
551	-658	1607	565	826	-125	988
552	-1056	1301	391	913	-539	773
553	780	811	652	652	314	566
554	-4577	903	-695	2347	-2004	476
555	-4715	918	-130	1087	-1986	548
556	-4011	1408	434	1652	-1690	737

TABLE 4

(Contd)

CTR NO.	T/R BLADE CHORD AT 21.5		T/R BLADE BEAM AT 21.5		T/R SHAFT TORQUE	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
544	1378	703	745	545	-	-
545	253	478	-566	122	500	184
546	393	450	-422	335	790	237
547	422	422	-231	510	843	263
548	450	450	-331	566	909	276
549	365	647	-366	479	738	158
550	506	562	-257	501	724	303
551	506	731	-109	562	896	395
552	253	759	-270	479	711	395
553	731	450	43	296	1146	461
554	28	422	-832	309	500	553
555	28	703	-797	292	751	803
556	253	647	-645	357	830	883

CTR NO.	T/R PITCH LINK RED		T/R SHAFT PERP. BEND		T/R SHAFT PARA. BEND	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
544	212	159	-91	680	-476	749
545	-53	53	202	312	-27	517
546	-10	74	18	643	-136	817
547	15	111	55	827	-177	994
548	5	153	18	937	-136	1035
549	10	95	183	624	-95	912
550	37	153	275	790	-163	1008
551	47	153	257	1036	-177	1049
552	-5	111	91	790	-109	844
553	47	111	-36	735	-177	994
554	-21	42	-91	569	-95	667
555	-10	53	128	753	-81	681
556	10	84	91	790	-13	994

TABLE 4

(Contd)

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
544	17.7	-	98.1	20.4	0	-
545	-0.7	-	104.4	22.5	80.5	-
546	4.0	-	102.3	21.5	59.1	-
547	4.5	-	102.9	48.3	57.3	-
548	5.2	-	102.9	55.6	54.9	-
549	4.7	-	105.0	44.1	56.1	-
550	5.2	-	106.5	50.9	54.2	-
551	5.5	-	103.9	58.8	52.4	-
552	3.4	-	99.2	43.5	61.0	-
553	7.6	-	100.2	37.2	41.4	-
554	0.5	-	102.9	10.5	74.4	-
555	-0.4	-	105.5	11.0	78.6	-
556	1.7	-	106.5	26.7	71.9	-

TABLE 5
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 Flt. 432-C
Ship AF60-3546 Date 14 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65 MEAN	T/R YOKE CHORD AT 2.65 OSC.
563	Hover I.G.E.	6600	0	583	583
564	Hover I.G.E.	6400	0	551	746
565	Hover I.G.E.	6200	0	746	583
566	Stabilized Level Flight	6600	40.5	-324	973
567	Stabilized Level Flight	6600	60.5	-340	924
568	Stabilized Level Flight	6600	78.0	-64	746
569	Stabilized Level Flight	6600	101.5	-65	681
570	Stabilized Level Flight	6600	113.0	-64	908
571	Stabilized Level Flight	6400	101.5	48	892
572	Stabilized Level Flight	6200	101.5	-259	1200

CTR NO.	T/R YOKE BEAM AT 2.65 MEAN	T/R YOKE BEAM AT 2.65 OSC.	T/R BLADE CHORD AT 11.0 MEAN	T/R BLADE CHORD AT 11.0 OSC.	T/R BLADE BEAM AT 11.0 MEAN	T/R BLADE BEAM AT 11.0 OSC.
563	-367	551	1043	521	226	353
564	-199	842	869	608	263	535
565	168	535	913	565	326	363
566	-2066	658	391	913	-989	353
567	-2281	750	347	695	-961	490
568	-1699	1025	565	652	-825	589
569	-979	1255	565	652	-281	753
570	-643	1224	695	782	-99	843
571	-367	1255	521	782	-9	825
572	-474	1423	347	1043	127	961

TABLE 5
(Contd)

CTR NO.	T/R BLADE BEAM AT 21.5		T/R BLADE CHORD AT 21.5		T/R SHAFT TORQUE	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
563	100	257	593	367	1977	263
564	104	331	678	395	1871	237
565	100	248	593	367	1884	224
566	-497	270	310	593	632	237
567	-488	279	141	480	698	276
568	-340	340	452	452	803	250
569	-226	427	254	480	896	342
570	-178	518	339	565	975	237
571	-148	497	226	565	738	237
572	-87	505	141	593	685	289

CTR NO.	T/R PITCH LINK RED		T/R SHAFT PERP. BEND		T/R SHAFT PARA. BEND	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
563	121	58	-128	716	-95	640
564	111	47	-91	716	-122	694
565	121	58	-91	643	-95	776
566	-37	79	-18	643	-54	681
567	-10	84	-55	496	-109	872
568	37	79	-165	753	-109	790
569	10	106	0	735	-109	817
570	-26	153	-128	716	0	872
571	5	132	-110	845	40	858
572	21	148	-110	845	-81	790

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
563	9.5	-	107.6	9.9	32.3	-
564	9.9	-	108.1	15.7	31.7	-
565	10.2	-	108.1	15.7	30.5	-
566	2.6	-	105.0	31.5	65.8	-
567	2.9	-	103.9	27.3	64.0	-
568	3.6	-	108.6	37.2	59.1	-
569	4.5	-	105.5	53.0	56.7	-
570	4.7	-	106.0	61.9	54.9	-
571	4.3	-	106.0	58.8	55.5	-
572	4.5	-	108.1	65.1	56.1	-

TABLE 6
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 Flt. 433-A
Ship AF60-3546 Date 15 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65 MEAN	T/R YOKE CHORD AT 2.65 OSC.
595	Stabilized Level Flight	6600	60.5	-236	741
596	Stabilized Level Flight	6600	78.0	-63	757
597	Stabilized Level Flight	6600	101.5	-47	899
598	Stabilized Level Flight	6400	101.5	63	883
599	Stabilized Level Flight	6200	101.5	-126	915

CTR NO.	T/R YOKE BEAM AT 2.65 MEAN	T/R YOKE BEAM AT 2.65 OSC.	T/R BLADE CHORD AT 11.0 MEAN	T/R BLADE CHORD AT 11.0 OSC.	T/R BLADE BEAM AT 11.0 MEAN	T/R BLADE BEAM AT 11.0 OSC.
595	-2128	535	391	739	-989	335
596	-1393	964	478	652	-598	562
597	-857	1163	565	739	-154	698
598	-566	1148	478	826	45	735
599	-352	1331	478	826	-72	762

CTR NO.	T/R BLADE BEAM AT 21.5 MEAN	T/R BLADE BEAM AT 21.5 OSC.	T/R BLADE CHORD AT 21.5 MEAN	T/R BLADE CHORD AT 21.5 OSC.	T/R SHAFT TORQUE MEAN	T/R SHAFT TORQUE OSC.
595	-483	265	310	480	849	231
596	-327	327	310	480	952	154
597	-148	444	113	565	913	218
598	-56	475	169	621	733	321
599	-156	488	141	593	759	270

TABLE 6

(Contd)

CTR NO.	T/R PITCH LINK RED		T/R SHAFT PERP. BEND		T/R SHAFT PARA. BEND	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
595	31	52	-196	447	195	727
596	21	73	-53	662	153	797
597	10	115	53	697	279	783
598	0	136	-107	787	293	964
599	-15	110	17	876	209	797

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
595	4.6	-	95.5	14.7	55.5	-
596	4.6	-	95.0	36.2	53.6	-
597	4.7	-	96.0	56.1	55.2	-
598	4.8	-	96.0	60.3	53.9	-
599	4.7	-	97.6	59.8	56.7	-

TABLE 7
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 G.R. 108A
Ship AF60-3546 Date 18 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65 MEAN	T/R YOKE CHORD AT 2.65 OSC.
605	RPM Sweep 4000 to 6800	-	-	-31	2148
606	Neutral Pedal	6400	-	-63	2180
607	Neutral Pedal	6600	-	-110	2069
608	Neutral Pedal	6800	-	-316	2085
609	T/R Pitch Change Sweep	6600	-	-347	2243

CTR NO.	T/R YOKE BEAM AT 2.65 MEAN	T/R YOKE BEAM AT 2.65 OSC.	T/R BLADE CHORD AT 11.0 MEAN	T/R BLADE CHORD AT 11.0 OSC.	T/R BLADE BEAM AT 11.0 MEAN	T/R BLADE BEAM AT 11.0 OSC.
605	-1224	1071	482	1797	-618	728
606	-2310	841	394	1622	-964	564
607	-1652	877	219	1973	-637	691
608	-2356	765	350	1578	-1064	755
609	-107	1239	-438	2192	54	837

CTR NO.	T/R BLADE BEAM AT 21.5 MEAN	T/R BLADE BEAM AT 21.5 OSC.	T/R BLADE CHORD AT 21.5 MEAN	T/R BLADE CHORD AT 21.5 OSC.	T/R SHAFT TORQUE MEAN	T/R SHAFT TORQUE OSC.
605	-435	435	339	1132	949	922
606	-391	321	254	1103	962	276
607	-448	274	226	1301	975	210
608	-461	269	283	1188	975	263
609	591	426	-141	1443	2360	197

CTR NO.	T/R PITCH LINK RED MEAN	T/R PITCH LINK RED OSC.	T/R SHAFT PERP. BEND MEAN	T/R SHAFT PERP. BEND OSC.	T/R SHAFT PARA. BEND MEAN	T/R SHAFT PARA. BEND OSC.
605	41	62	-736	1582	-322	1218
606	36	67	-165	1196	-476	700
607	20	93	-331	1913	-210	1022
608	46	109	-956	2355	-322	1190
609	104	104	-368	1251	-378	826

TABLE 7

(Contd)

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
605	5.7	-	91.6	37.8	50.2	-
606	5.2	-	92.2	16.5	52.7	-
607	5.2	-	93.7	39.8	51.4	-
608	5.2	-	94.2	19.6	51.1	-
609	10.4	-	96.8	52.3	26.0	-

TABLE 8
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 G.R. 109A
Ship AF60-3546 Date 20 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65	
				MEAN	OSC.
624	RPM Sweep 4000 to 6800	-	-	-79	2101
625	Neutral Pedal	6400	-	-237	1975
626	Neutral Pedal	6600	-	-379	2085
627	Neutral Pedal	6800	-	-379	2148
628	T/R Pitch Change Sweep	6600	-	-379	2654

CTR NO.	T/R YOKE BEAM AT 2.65		T/R BLADE CHORD AT 11.0		T/R BLADE BEAM AT 11.0	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
624	-2891	719	261	1740	-1157	569
625	-2692	428	261	1566	-1112	329
626	-2738	382	261	1740	-1103	356
627	-2845	550	217	1783	-1103	462
628	1377	1071	-435	2175	17	640

CTR NO.	T/R BLADE BEAM AT 21.5		T/R BLADE CHORD AT 21.5		T/R SHAFT TORQUE	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
624	-428	325	-28	1148	303	567
625	-411	197	56	1064	726	250
626	-402	197	56	1120	858	250
627	-377	231	84	1092	831	277
628	102	377	-252	1540	831	435

CTR NO.	T/R PITCH LINK RED		T/R SHAFT PERP. BEND		T/R SHAFT PARA. BEND	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
624	78	47	-626	1628	-252	1157
625	57	26	18	984	-505	558
626	57	36	-375	1235	-412	758
627	94	42	-483	1414	-279	970
628	168	105	-375	1593	-465	837

TABLE 8

(Contd)

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
624	4.8	-	104.2	12.7	53.0	-
625	4.8	-	103.7	4.7	52.4	-
626	4.8	-	103.2	7.4	51.8	-
627	4.7	-	103.2	7.4	53.6	-
628	13.7	-	104.2	26.6	13.4	-

TABLE 9

TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 Flt. 434-A

Ship AF60-3546 Date 23 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65	
				MEAN	OSC.
637	Hover I.G.E.	6600	0	66	1569
638	Stabilized Level Flight	6600	59.5	-200	1770

CTR NO.	T/R YOKE BEAM AT 2.65		T/R BLADE CHORD AT 11.0		T/R BLADE BEAM AT 11.0	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
637	-1285	795	652	1348	-198	612
638	-1453	1025	348	1392	-531	585

CTR NO.	T/R BLADE BEAM AT 21.5		T/R BLADE CHORD AT 21.5		T/R SHAFT TORQUE	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
637	-4	343	254	933	1548	283
638	-421	282	28	877	1032	283

CTR NO.	T/R PITCH LINK RED		T/R SHAFT PERP. BEND		T/R SHAFT PARA. BEND	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
637	89	68	-447	1306	-464	819
638	-5	78	268	1807	-464	955

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
637	8.1	-	96.4	14.3	39.6	-
638	4.4	-	98.4	42.0	55.2	-

TABLE 10
TAIL ROTOR LOADS AND DISPLACEMENT DATA

Model UH-1B 192 [illegible] 434-B
Ship AF60-3546 Date 22 January 1965

CTR NO.	TEST CONDITION	N_{II} RPM	V_{CAL} KN.	T/R YOKE CHORD AT 2.65 MEAN	T/R YOKE CHORD AT 2.65 OSC.
642	T/R Pitch Change Sweep (On Ground)	6600	-	-500	2736
643	Hover to Left Turn	6600	0	-317	2285
644	Hover to Right Turn	6600	0	400	2469
645	Stabilized Level Flight	6600	60.5	-150	2519
646	Stabilized Level Flight	6600	78.0	-166	1801
647	Stabilized Level Flight	6600	101.5	-233	1668
648	Stabilized Level Flight	6400	101.5	-66	2269
649	Stabilized Level Flight	6200	101.5	-433	469

CTR NO.	T/R YOKE BEAM AT 2.65 MEAN	T/R YOKE BEAM AT 2.65 OSC.	T/R BLADE CHORD AT 11.0 MEAN	T/R BLADE CHORD AT 11.0 OSC.	T/R BLADE BEAM AT 11.0 MEAN	T/R BLADE BEAM AT 11.0 OSC.
642	-6876	318	-478	1956	-3254	197
643	-4447	531	130	1956	-2040	350
644	3294	895	608	1913	2490	674
645	-2489	607	0	1826	-970	521
646	-1578	759	260	1478	-764	584
647	-1017	986	391	1347	-323	647
648	-652	1138	260	1652	-62	872
649	-531	1229	130	1956	-89	827

CTR NO.	T/R BLADE BEAM AT 21.5 MEAN	T/R BLADE BEAM AT 21.5 OSC.	T/R BLADE CHORD AT 21.5 MEAN	T/R BLADE CHORD AT 21.5 OSC.	T/R SHAFT TORQUE MEAN	T/R SHAFT TORQUE OSC.
642	-1304	207	-280	1344	913	270
643	-803	293	224	1232	875	360
644	1036	423	112	1232	4543	64
645	-285	267	-504	1176	707	270
646	-280	289	-252	980	720	257
647	-95	371	-28	980	746	205
648	69	328	-84	1092	772	180
649	-120	423	-168	1232	707	321

TABLE 10

(Contd)

CTR NO.	T/R PITCH LINK RED		T/R SHAFT PERP. BEND		T/R SHAFT PARA. BEND	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
642	-89	36	-465	894	-571	677
643	47	184	-322	2075	-598	1156
644	26	173	-357	1037	-558	1063
645	10	84	-125	1091	-717	903
646	5	68	-572	1145	-624	810
647	-310	78	-518	1198	-6[illegible]1	797
648	-284	84	-429	1073	-558	850
649	36	78	-322	894	-598	970

CTR NO.	T/R BLADE ANGLE		T/R FLAPPING ANGLE		DIR. CONT. PED. POS.	
	MEAN	OSC.	MEAN	OSC.	MEAN	OSC.
642	-6.9	-	98.2	17.1	100.0	-
643	0	-	96.7	65.5	77.5	-
644	15.9	-	95.1	97.2	4.2	-
645	2.2	-	97.2	28.6	65.7	-
646	3.1	-	96.7	41.6	61.2	-
647	4.2	-	97.7	53.0	55.1	-
648	4.2	-	97.2	59.8	56.3	-
649	4.1	-	99.8	59.2	55.7	-

FIGURE 1. VIEW OF TAIL ROTOR ASSEMBLY SHOWING INSTALLATION OF THE EROSION PROTECTION BOOTS.

FIGURE 2. VIEW OF TAIL ROTOR BLADE SHOWING THE EROSION PROTECTION BOOT WITH 25 PERCENT OF THE MATERIAL REMOVED.

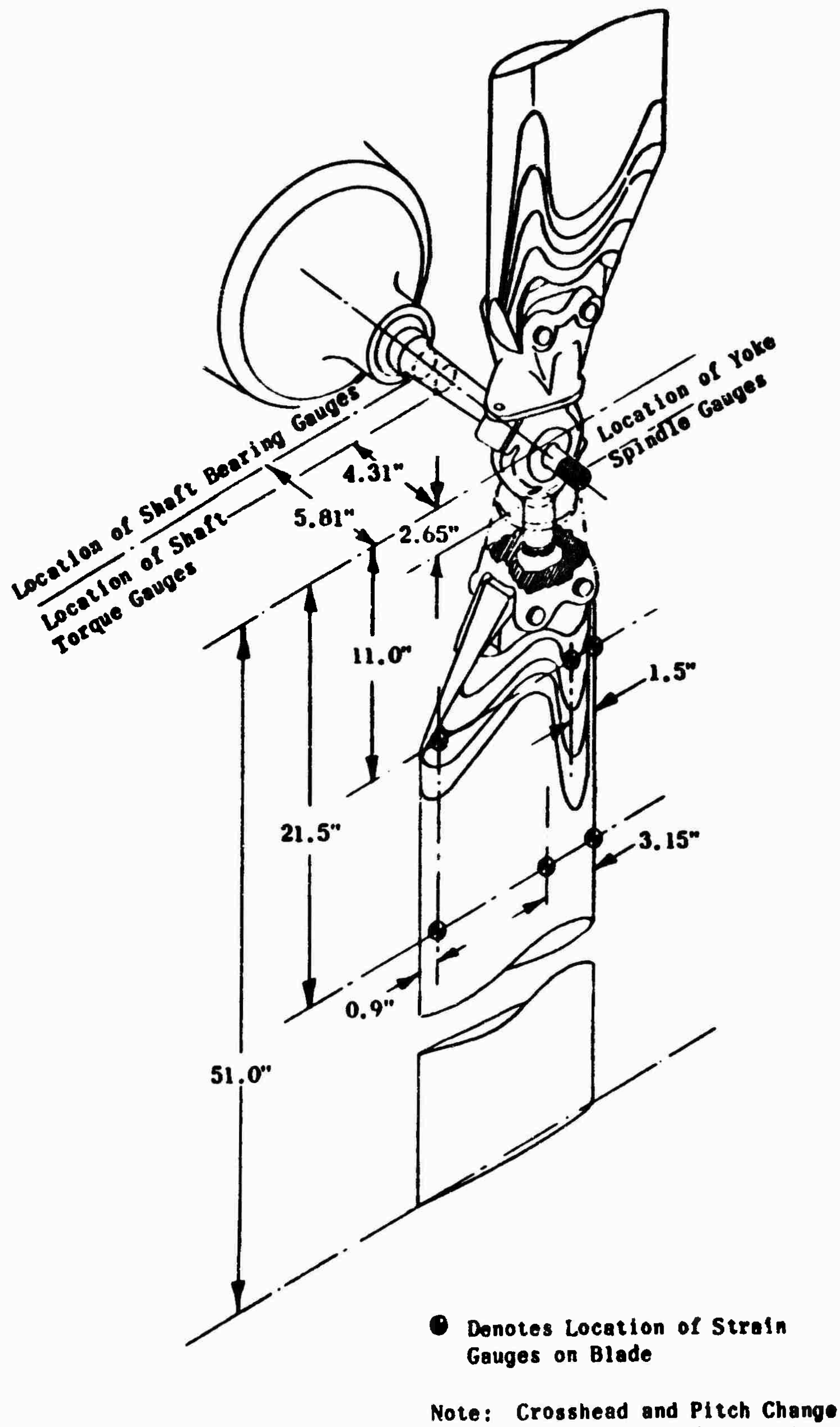

FIGURE 3. DIAGRAMMATIC VIEW OF TAIL ROTOR SHOWING LOCATIONS OF INSTRUMENTATION STRAIN GAUGES ON SHAFT, YOKE, AND BLADE.

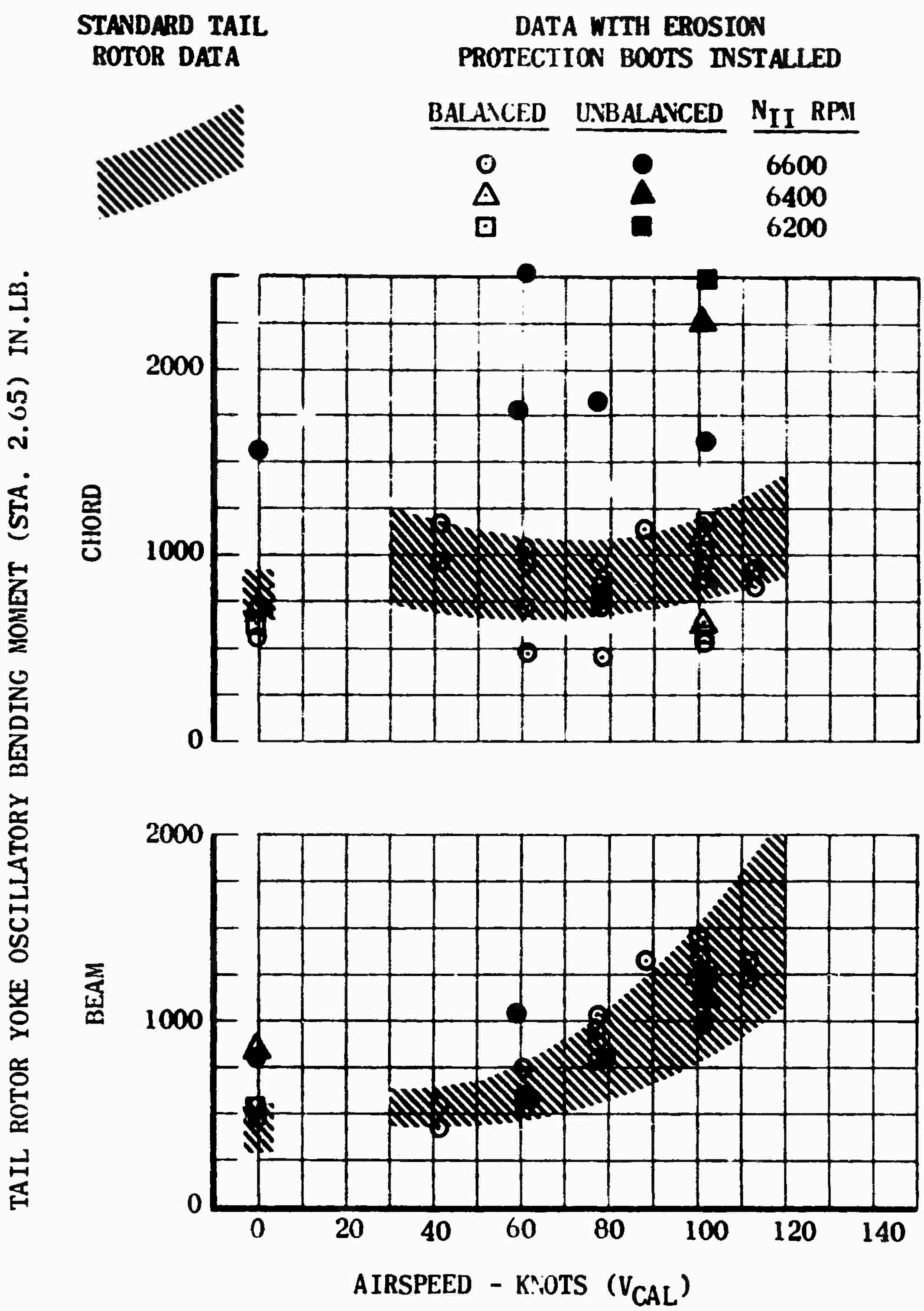

FIGURE 4. TAIL ROTOR YOKE BEAM AND CHORD OSCILLATORY BENDING MOMENT (STA. 2.65) VERSUS AIRSPEED.

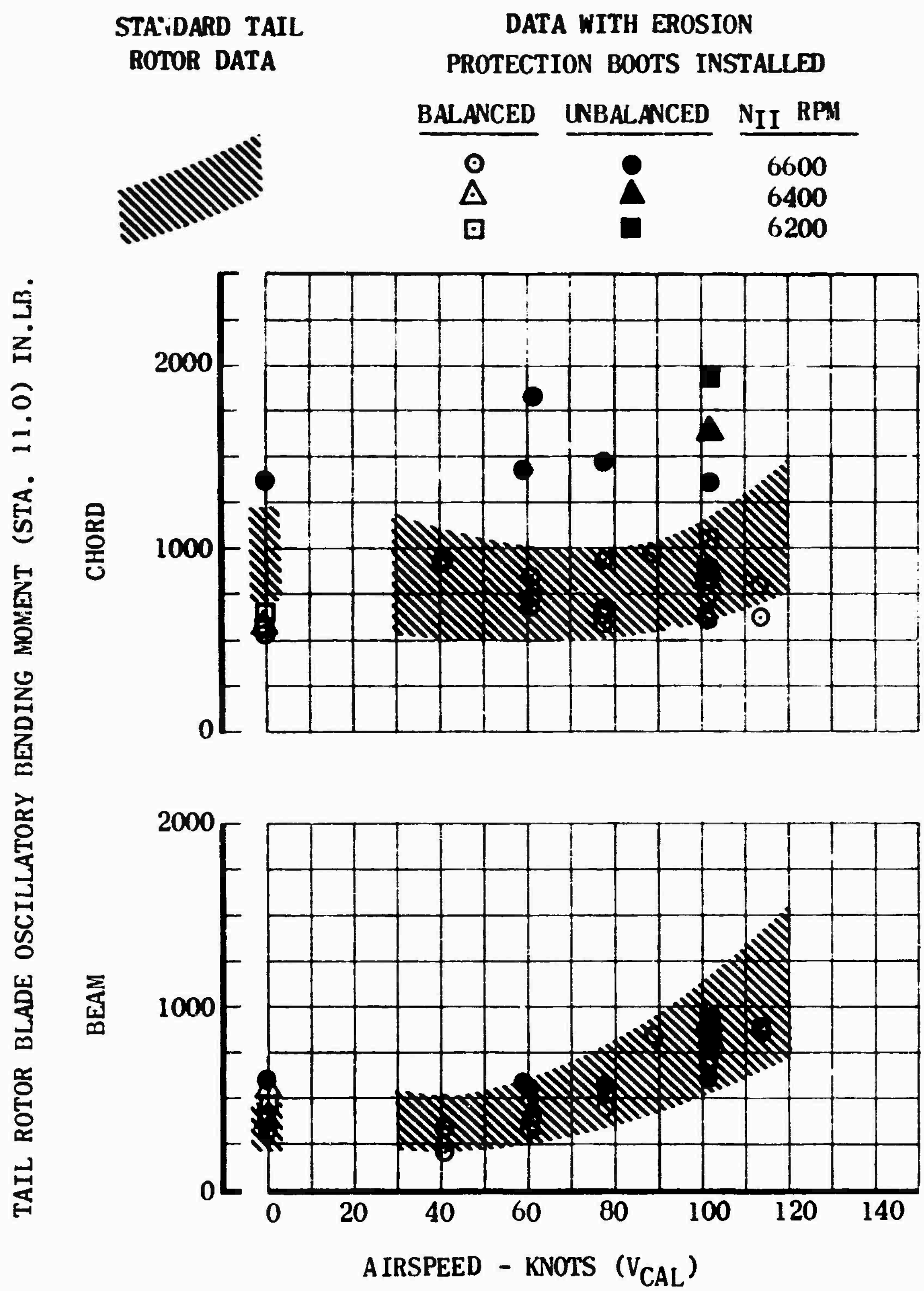

FIGURE 5. TAIL ROTOR BLADE BEAM AND CHORD OSCILLATORY BENDING MOMENT (STA. 11.0) VERSUS AIRSPEED.

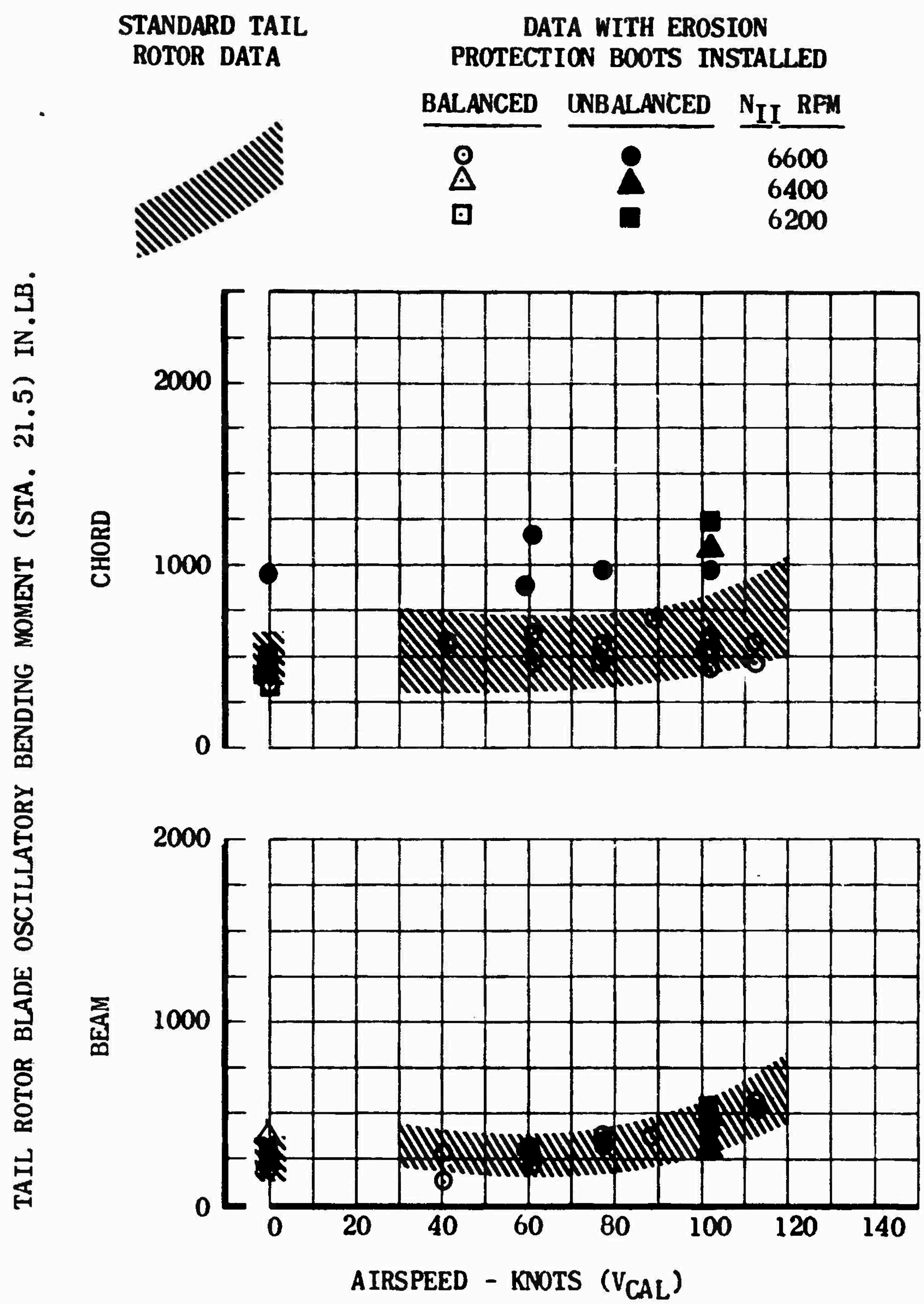

FIGURE 6. TAIL ROTOR BLADE BEAM AND CHORD OSCILLATORY BENDING MOMENTS (STA. 21.5) VERSUS AIRSPEED.

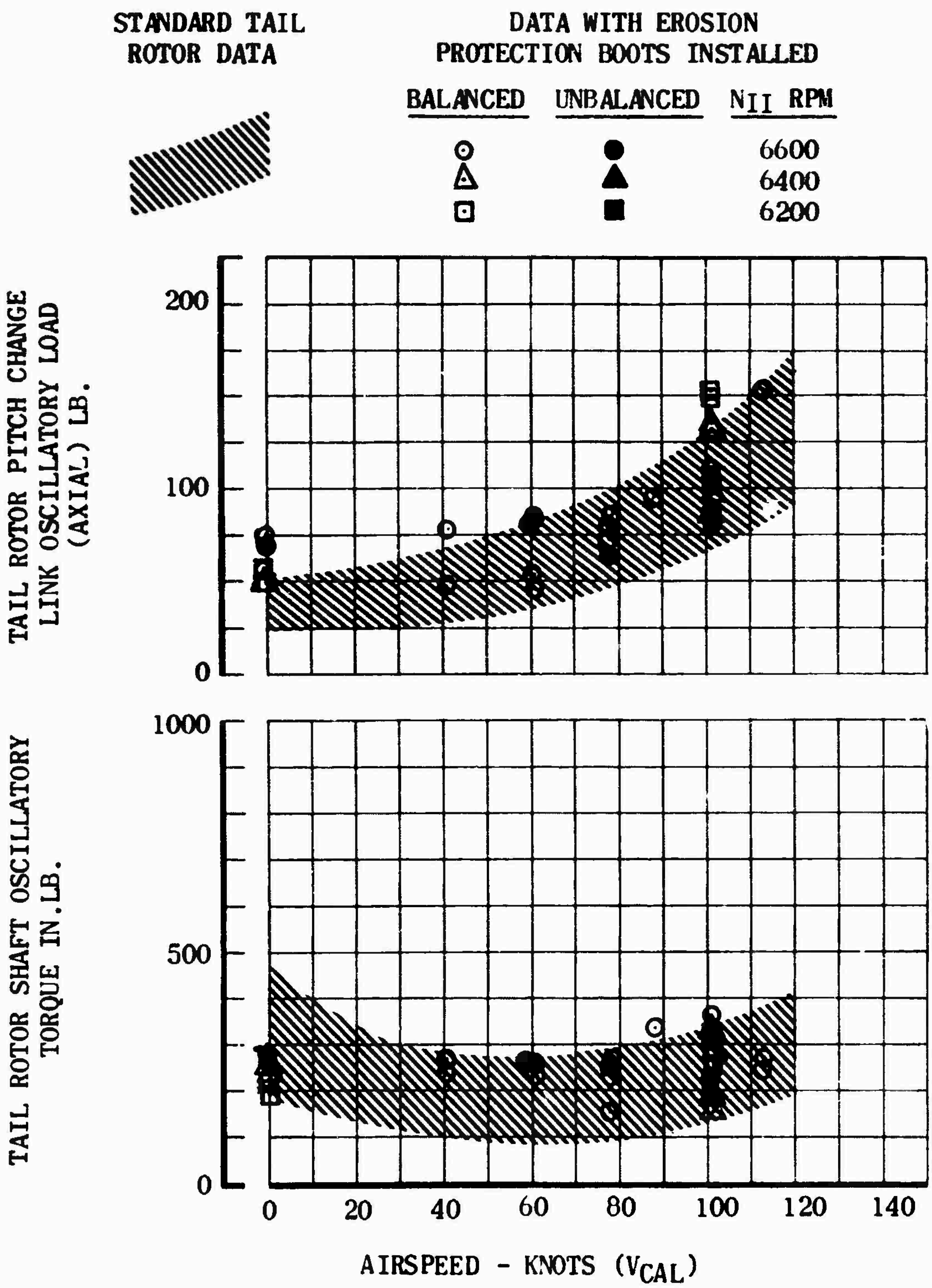

FIGURE 7. TAIL ROTOR SHAFT OSCILLATORY TORQUE AND PITCH CHANGE LINK OSCILLATORY LOAD VERSUS AIRSPEED.

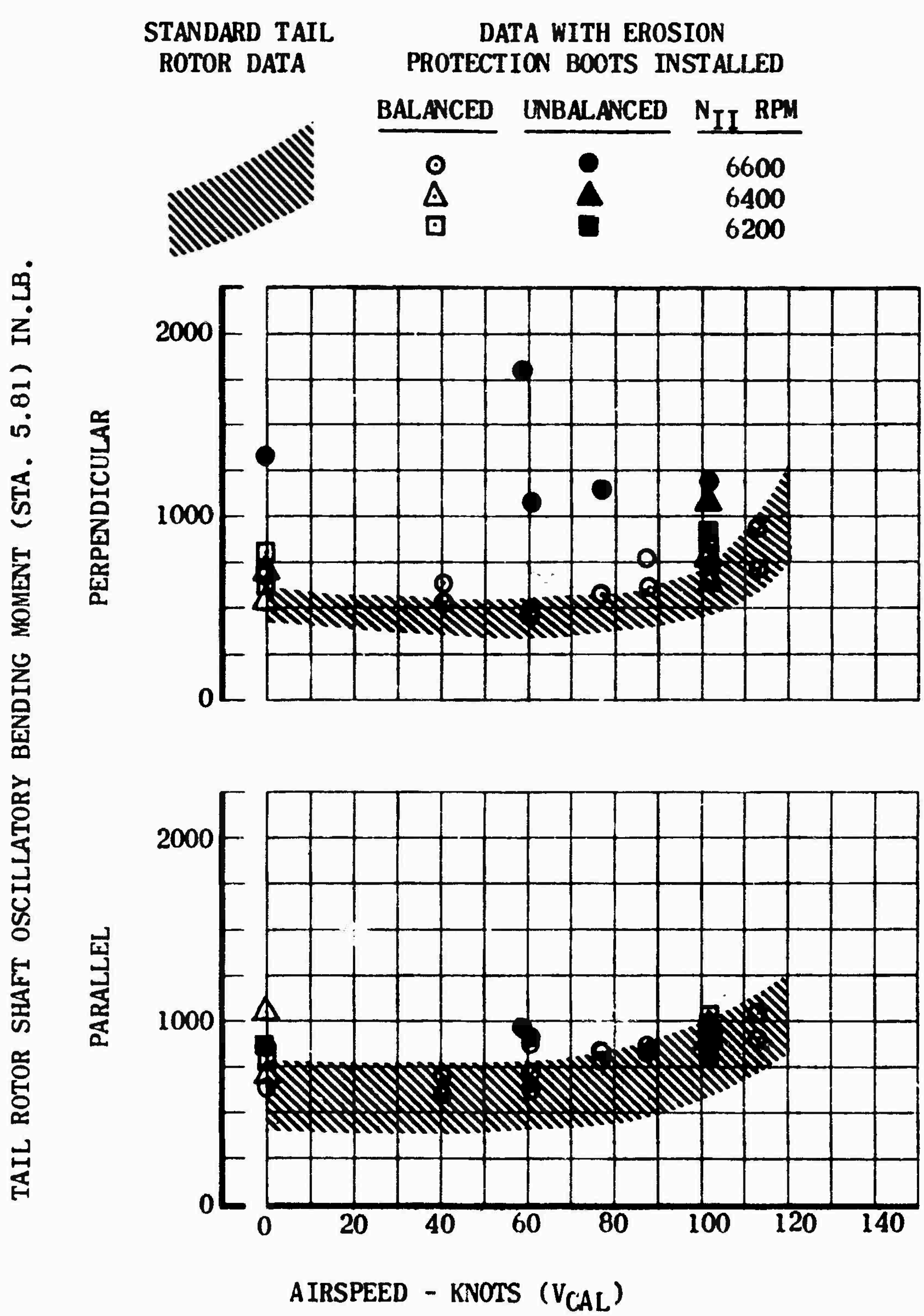

FIGURE 8. TAIL ROTOR SHAFT PARALLEL AND PERPENDICULAR BENDING MOMENT VERSUS AIRSPEED.

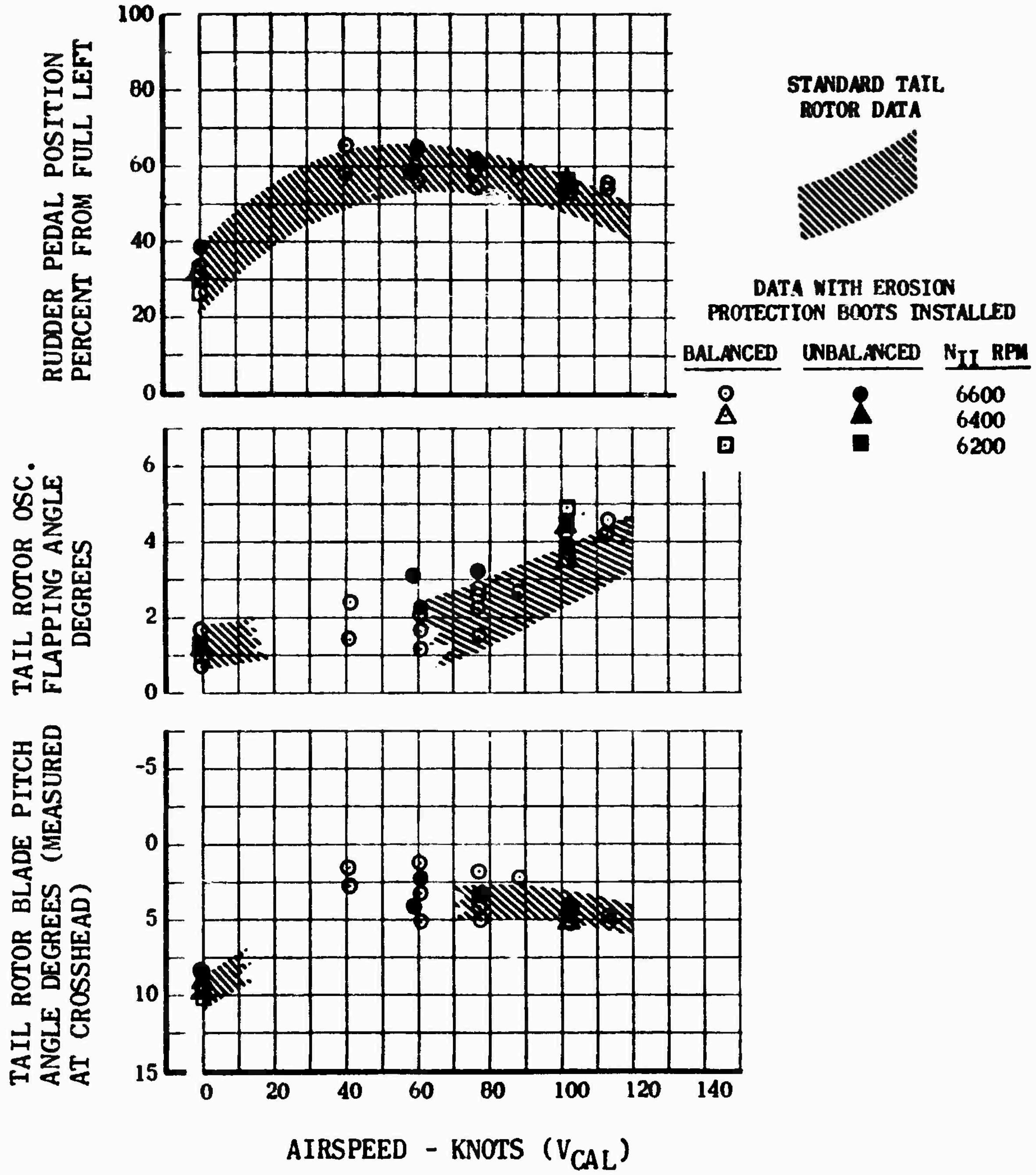

FIGURE 9. TAIL ROTOR BLADE PITCH ANGLE, OSCILLATORY FLAPPING ANGLE AND RUDDER PEDAL POSITION VERSUS AIRSPEED.